A LIQUID CRYSTAL DISPLAY HAVING REPAIR LINES AND METHODS OF REPAIRING THE SAME

Background of the Invention

The present invention relates to a liquid crystal display and, more particularly, a liquid crystal display having repair lines and methods of repairing a defect thereof.

The liquid crystal display (LCD) is a device comprising a thin film transistor substrate, a color filter substrate, and liquid crystals inserted between the two, whereby the electro-optical effects of the inserted liquid crystals are used for display purposes.

The display method above may use simple matrix method or active matrix method. For LCDs using the active matrix method, thin film transistors (TFT) are generally used as switching devices for controlling operation of each pixel, and the TFT substrate of such LCDs comprises TFTs, pixel electrodes, gate lines for applying signals to pixels aligned in matrix formation, and data lines for applying picture signals.

When a data line of the active matrix LCD is disconnected or defective (hereinafter "disconnection" will be used to refer to either a disconnection or defect in a data line), the disconnection can be repaired by using lines within the unit pixel or using repair lines placed outside of the substrate of LCD. Under the former method, one must first locate the disconnected data line and then find the point of disconnection on the data line. However, it is difficult to find the point of disconnection and the repair becomes impossible when the disconnection occurs over two or more pixels.

Under the latter method, it is only required to locate the disconnected data line and there is no need to find the point of disconnection. Then only the crossing points of the disconnected data line and the repair line has to be shorted by laser, allowing for a much simpler repairing method.

From this point, the wiring structure of TFT substrate of conventional LCD and its disconnection repairing method shall be explained in detail. Fig. 1 is a wiring structure of

conventional TFT substrate having two repair lines in the shape of a closed loop. As shown, a plurality of gate lines (G_1~G_n) are arranged in horizontal direction, and a plurality of data lines (D_1~D_m) are arranged in vertical direction, and each of gate lines and data lines has an input pad on one end. A pixel is defined by the gate line and the data line. An active area consists of all the pixels.

On the outside of the active area 50 having (n x m) number of pixels, two repair lines 100, 200 form two closed loop, each overlapping all data lines and gate lines at two points.

Fig. 2 illustrates a repairing method of the TFT substrate shown in Fig. 1. Suppose data line D_4 and data line D_7 are disconnected at point a and point b, respectively. The data line D_4 may be repaired by shorting its two crossing points a_1, a_2 with the repair line 100 and disconnecting two points marked //, of the repair line 100 with laser so that picture signals could flow through the shorter path. In this way, a picture signal is sent to the disconnected point a of the data line D_4 by path P_1 from the top, and the signal is sent to the remaining portion of the data line D_4 by path P_1'.

Then the data line D_7 may be repaired by shorting its two crossing points b_1, b_2 with the repair line 200 and disconnecting two points of the data line D_7 marked by //, of the repair line 200 with laser. In this way picture signals as with before are sent to the disconnected point b from top by path P_2, and the signal is sent to the remaining portion of the data line D_7 below the disconnection by path P_2'.

However, the TFT substrate having repair lines outside of the active area in closed loops would experience substantial electrical resistance when repairing a disconnected data line in the middle of active area since the signal path for sending signals to the data line below the disconnection becomes quite lengthy. In addition to large resistance, there would be a substantial parasitic capacitance increase since the repair line overlaps numerous data

and gate lines, resulting in increase of RC delay and signal distortion.

Therefore, the conventional repair line structure above is not suitable for a large LCD with many data lines and gate lines. It is also inconvenient since it involves an additional step of disconnecting the repair line to guide the flow of signals through the shorter path around the repair line, as well as a step of shorting the crossing points of the repair line and the disconnected data line. Moreover, the most data lines that could be repaired are limited to four.

Summary of the Invention

An object of the present invention is to solve the problems associated with the conventional repair wire line structure by repeatedly forming a repair line for each of a predetermined number of data lines, thereby minimizing the increase of RC delay resulting from the repair and making data line repair easy.

Accordingly, a liquid crystal display according to the present invention comprises: a plurality of gate lines arranged in horizontal direction; a plurality of data lines arranged perpendicular thereto; a plurality of repair lines formed repeatedly for each of a predetermined number of data lines, the repair lines crossing the gate lines in the active area.

According to a one preferred embodiment of the present invention, the repair line comprises an upper portion crossing top of the data lines, a lower portion crossing bottom of the data lines, and a middle portion which is parallel to the data line connects the upper and the lower portions. A repair line is formed repeatedly for each data-line block including data lines in any multiple of three. A disconnected data line is repaired by shorting the crossing points of the data line and the repair line corresponding to the data-line block of the disconnected data line, making its repair procedure simpler and resulting in shorter signal path after the repair in comparison to the conventional repair method.

Another preferred embodiment of the present invention is directed to eliminating a problem of noticeable pixel brightness difference resulting after the repair with respect to green data line. The middle portion of the repair line is formed adjacent to the green data line and they are connected at one or more points to minimize the generation of RC delay due to the repair so that difference in green pixel brightness would not be noticed.

In another preferred embodiment of the present invention in connection with a liquid crystal display having duplicate gate lines, a repair line includes only a middle portion which is placed parallel to the data lines and secondary gate lines serve as the upper and lower portions of the repair line.

Brief Description of the Drawings

The forgoing and other objects, features and advantages of the present invention will become more readily apparent from the following detailed description of preferred embodiments of the present invention which proceeds with reference to the accompanying drawings, wherein:

Fig. 1 is a wiring structure of a conventional TFT substrate having two repair lines formed in closed loops;

Fig. 2 illustrates repairing method of the TFT substrate shown in Fig.1;

Figs. 3 to 8 show the wiring structure of TFT LCD according to a first preferred embodiment of the present invention;

Figs. 9 illustrates repairing method of a disconnected data line in the TFT substrate of Fig. 6;

Fig. 10 shows the wiring structure of TFT LCD according to a second preferred embodiment of the present invention;

Figs. 11 and 12 illustrate repairing method of a disconnected green and red data lines

of Fig. 10;

Figs. 13 and 14 show equivalent circuits which represent electrical resistance and parasitic capacitance resulting from the electrical lines of TFT LCD according to the first and second preferred embodiment of the present invention;

Fig. 15 illustrates a repairing method of a disconnected data line of TFT LCD having duplicate gate lines according to a third preferred embodiment of the present invention;

Figs. 16 and 17 illustrate a repairing method of a disconnected data line of TFT LCD having duplicate gate lines and repair lines parallel with data lines according to a fourth preferred embodiment of the present invention; and

Fig. 18 shows a wiring structure of an LCD having duplicate gate lines and connections according to a fifth preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiments

Figs. 3 to 8 shows the wiring structure of TFT LCD according to a first preferred embodiment of the present invention. As shown, a plurality of gate lines ($G_1 \sim G_n$) are arranged in parallel to each other in horizontal direction, and a plurality of data lines ($D_1 \sim D_m$) are arranged perpendicular thereto. Input pads 1, 2 which receives electrical signals from external source are connected to one end of the gate lines and data lines. A plurality of repair lines 300 for repairing disconnected data lines are formed wherein each repair line 300 corresponds to each data-line block ($B_1 \sim B_n$). The data-line block comprises three data lines, whereby all data lines within a data-line block overlap with the corresponding repair line 300.

The repair line 300 comprises a first horizontal portion 300a which transverses the upper end of the data lines whereto the input pads 2 is connected, a second horizontal portion 300b which transverses the other end of the data lines, and a vertical portion 300c, formed in parallel to the data lines, which connects the first horizontal portion 300a and the second

horizontal portion 300b. The vertical portion 300c transverses the gate lines in the active area, and is placed adjacent to the data line of the data-line block to which it correspond.

In Figs. 3 to 5, the first and second horizontal portions 300a, 300b transverse only the three data lines within a data-line block.

In Figs. 3 and 4, the vertical portion 300c is placed between two data-line blocks. In Fig. 3, the vertical portion 300c connects the right ends of the first horizontal portion 300a and the second horizontal portion 300b. In Fig. 4, on the other hand, the vertical portion 300c connects the left ends of the first horizontal portion 300a and the second horizontal portion 300b.

The vertical portion 300c may also be placed within a data-line block, i.e., between the data lines of a data-line block. As an example, the vertical portion 300c is placed between the first and the second data lines in Fig. 5.

Figs. 6 to 8 illustrate the TFT substrate wherein the first horizontal portion 300a and the second horizontal portion 300b of the repair line 300 transverse the data lines (six data lines) of two adjacent data-line blocks. Each data line is crossed by two repair lines 300. The first and second horizontal portions 300a, 300b of one of the repair line 300 cross the data lines from inside, and the first and second horizontal portions 300a, 300b of the other repair line cross the data line from outside.

In Figs. 6 and 7, the vertical portion 300c is placed between two data-line blocks. In Fig. 6, the vertical portion 300c is connected to one end of the first horizontal portion 300a and the second horizontal portion 300b. In Fig. 7, the vertical portion 300c connects to the middle of the first horizontal portion 300a and the second horizontal portion 300b.

On the other hand, a first embodiment of the present invention illustrated in Fig. 8 shows that the vertical portion 300c is placed within one of its two corresponding data-line block.

In addition, the present invention may also be worked by increasing the size of a data-line block from three to six data lines. The wiring structure would remain the same as shown in Figs. 3 to 8, except the number of data lines in a data-line block would be increased accordingly, whereby the first and second horizontal portions 300a, 300b each cross six data lines or twelve data lines, depending on the particular type of embodiment being worked.

Hereinafter, for Figs. 3 to 5, a repair line which crosses data lines will be referred as the repair line of the data-line block to which the crossed data lines belong, and for Figs. 6 to 8, a repair line which crosses data lines from inside will be referred as the repair line of the data-line block to which the crossed data lines belong.

Fig. 9 illustrates a repairing method of the TFT substrate of Fig. 6. As shown, suppose that the data lines D_1, D_2 of the first data-line block B_1 are disconnected. In order to repair the data line D_1, the crossing points c_1, c_2 of the data line D_1 and the repair line of the first data-line block are shorted (▲) with laser. As a result, picture signals are sent from the input pad 2 to the disconnection c by path P_1, and sent to the remaining portion below the disconnection c by path P1'.

Next in order to repair the data line D_2, the crossing points d_1, d_2 of the data line D_2 and the repair line of the second data-line block are shorted (▲) with laser. As a result, picture signals are sent from the input pad 2 to the disconnection d by path P_2, and sent to the remaining portion below the disconnection d by path P_2'.

As illustrated, the repair signal path for sending picture signals to a disconnected data line would be shorter than that of the conventional repair line structure, irrespective of where the disconnection occurs if the above repair line structure is used.

Moreover, in comparison to the conventional repair line structure in the form of a closed loop which allows for repairing of only four data lines, many more repairs may be made under the present invention since a plurality of repair lines are formed repeatedly on the

TFT substrate. Further, since the repair lines under the present invention has an opening on one side in contrast to a closed loop, the only necessary repairing step is to short the two crossing points of the repair line and the disconnected data line. There is no need for an additional step of disconnecting one side of the repair line to direct the flow of signal to one path.

The above repairing method also applies to an embodiment of the present invention wherein the horizontal portions of a repair line cross six data lines.

With respect to the first preferred embodiment, the signal path after the repair is substantially longer than the signal path before the repair; consequently, RC delay resulting from the resistance and capacitance after the repair is greater than that before the repair. Therefore, the pixel brightness varies slightly after the repair. This slight difference in pixel brightness does not pose a problem in connection with repairing of red and blue data lines, but this is not the case when a green data line is repaired since human eyes are much more sensitive to the wave length of the green light (550 nm) than that of other lights.

That is, suppose red, blue, and green data lines each are disconnected at the same location and repaired according to the first preferred embodiment. The repaired data lines each would have identical RC delay value resulting from resistance and capacitance generated from the signal path after the repair and would have identical difference in pixel brightness. However, one would not notice the difference in pixel brightness of the repaired red data line and the repaired blue data line, but would notice the difference in pixel brightness of the repaired green data line.

The second first preferred embodiment of the present invention concerns minimizing the difference in pixel brightness of green data line. Fig. 10 illustrates the wiring structure of the second first preferred embodiment. In Fig. 10, data lines are arranged repeatedly in order of blue, red, green data lines from the left, and the vertical portion 300c of the repair line 300

is placed on the right side of the green data line. The vertical portion 300c is connected to the mid-point of the green data line. The connection (m_1~m_i) as should be explained hereinafter reduces resistance and parasitic capacitance resulting from the data line repair, thereby difference in green light brightness is minimized after the repair.

The modification of adding a connection between the green data line and the vertical portion 300c may be made on any of the embodiments illustrated in Figs. 3 to 8.

Figs. 11 and 12 illustrate a repairing method of the TFT substrate having connections m_1~m_i between the vertical portions 300c and the green data lines. More specifically, Fig. 11 illustrates repairing method when the green data line D_3 is disconnected, and Fig. 12 illustrates repairing method when the red data line D_2 is disconnected.

As shown in Fig. 11, when the green data line D_3 is disconnected, the crossing points e_1, e_2, of the green data line D_3 and its repair line 300 are shorted (▲) with laser. As a result, picture signals are sent directly to the disconnection e from the input pad 2, and to the data line below the disconnection e by means of the repair line 300 and the connection m_1.

As shown in Fig. 12, when a red data line is disconnected, the connection of its repair line is located and disconnected with laser. Then the crossing points f_1, f_2 of the red data line and its repair lines are shorted (▲) with laser. As a result, picture signals are sent directly to the disconnection f of the red data line from the input pad 2, and to the data line below the disconnection f by means of the repair line 300. Although the above method concerns repairing of a disconnected red data line, similar method may be used for repairing of a disconnected blue data line.

The effectiveness of adding the connections m_1~m_i will be explained below by comparing resistance and capacitance resulting from repairing a disconnected green data line under two different embodiments, one including the connections m_1~m_i and the other without it.

Figs. 13 and 14 shows equivalent circuits of resistance and capacitance appearing on a data line repaired according to the first and second first preferred embodiments, wherein the disconnection had occurred nearby the input pad 2.

Suppose a disconnected green data line is being repaired. The picture signal being sent to the portion of the green data line below the disconnection would experience resistance resulting from the paths of the data line and the repair line and would experience parasitic capacitance resulting from overlap of the repair and data lines with the gate lines. The resulting resistance and parasitic capacitance are illustrated in Figs. 13 and 14. A node l on the first horizontal portion and a node n on the second horizontal portion are the crossing points of the disconnected data line and its repair line, and nodes i_1, i_2 are mid-points of the vertical portion 300c and the disconnected data line, respectively, and a node o is the disconnection point.

Since the disconnection is assumed to have occurred very close to the input pad, the length from the input pad 2 to the mid-point of the repair line is almost the same as the length from the disconnection to the mid-point of the disconnected data line, as with the number of gate lines overlapped by the respective path.

Assuming that the data line and the repair line are both made of the same material and have the same cross sectional dimensions, it may be assumed that the resistance and the parasitic capacitance between the nodes l and i_1 are the same as those between the nodes o and i_2, and the resistance and the parasitic capacitance between the nodes i1 and n are the same as those between the nodes i_2 and n.

However, this is not entirely true because there is a TFT on the crossing point of the data line and the gate line unlike in the overlap of the repair line and the gate line, resulting in formation of parasitic capacitance in the former overlap. Therefore, in reality total parasitic capacitance generated between the nodes o and n is greater than that generated between the

nodes l and n.

With this in mind, the resistance and capacitance values in the nodes may be denoted as follows. When the resistance between the nodes o and i_2 and between the nodes i_2 to n are denoted as R_1 and R_2, respectively, the resistance between the nodes l and i_1 and between the nodes i_1 and n may be denoted as R_1 and R_2, respectively. When the parasitic capacitance between the nodes o and i_2 and between the nodes i_2 and n are denoted as C_1 and C_2, respectively, the parasitic capacitance between the nodes l and i_1 and between the nodes i_1 and n may be denoted as kC_1 and kC_2, respectively, where k is a constant less than 1 inserted to offset the lower parasitic capacitance generated by the repair line relative to the data line.

In the equivalent circuit of Fig. 13, the total RC delay resulting from transmittal of signals from node G to node O is accumulation of RC delay resulting from (R_1 x kC_1), (R_2 x kC_2), (R_2 x C_2), and (R_1 x C_1).

In comparison, in the equivalent circuit of Fig. 14 wherein in the connection m_1 is inserted between the repair line and the data line, the total RC delay resulting from transmittal of signal from node G to node O is accumulation of RC delay resulting from (R_1 x kC_1) and (R_1 x C_1). Therefore, the total RC delay value according to the second first preferred embodiment is much less than that of the first preferred embodiment.

Moreover, if connections are added at the upper and lower parts of the green data line and the repair line in addition to the connection m_1 at the mid-point, there is no need to repair a green data line when a disconnection results thereon.

Fig. 15 illustrates a third first preferred embodiment of the present invention on repairing method of a disconnected data line in the TFT substrate having duplicate gate lines. The duplicate gate line comprises a primary branch which forms a plurality of the gate electrodes of TFT transistors, and a secondary branch which is connected to the primary branch. With respect to such TFT substrates, the technique of the second first preferred

embodiment may be worked without inserting a connection between the green data line and the repair line. The structure of the repair line illustrated in Fig. 15 is the same as that illustrated in Fig. 5. The first data line in each data-line block is a green data line.

Assume a green data line is disconnected. In order to repair the green data line, the crossing point g_1 of the first horizontal line 300a and the green data line and the crossing point g_2 of the second horizontal line 300b and the green data line are shorted (▲) with laser. The crossing point g_3 of the secondary branch G_r and the green data line, and the crossing point g_4 of the secondary branch G_r located at the middle of the active region and the vertical portion 300c of the repair line 300 are shorted (▲) with laser. Then points // outside nodes g_3 and g_4 are disconnected with laser in order prevent gate line signals from being applied to the green data line. Nodes g_3 and g_4 performs the same function as the connection m_1 of the second first preferred embodiment. Although the third first preferred embodiment used a secondary branch G_r located at the middle of the active region in place of the connection m_1, the repair according to the third first preferred embodiment may be performed by using a secondary branch G_r located at places other than at the middle of the active region.

On the other hand, instead of using repair lines having two horizontal portions and a vertical portion, it is possible to use repair lines having only a vertical portion, i.e., a portion which is parallel to data lines, in a TFT substrate having duplicate of gate lines. Note the vertical portion itself comprises the entire repair line.

Fig. 16 shows the fourth first preferred embodiment of the present invention having such a wiring structure. A repair line 310 is placed parallel to data lines and adjacent to a green data line.

Assume that the green data line is disconnected and the exact location of the point of disconnection is not known. The green data line may be repaired as follows. First, the secondary branch G_r of the uppermost gate line G_1, the secondary branch G_r of the central

gate line G_i, the secondary branch G_r of the lowermost gate line G_m are shorted (▲) with laser on their crossing points with the disconnected green data line and the repair line 310 adjacent thereto, i.e., the points h_1, h_2, h_3, h_4, h_5, and h_6. The points h_7, h_8, h_9, h_{10}, h_{11}, h_{12} outside the shorted portions of the secondary branches G_r are disconnected. As a result, the shorted portion h_1 and h_2 and the shorted portion h_3 and h_4 functions as the horizontal portions 300a, 300b of the repair line in Fig. 15, and the shorted portion h_5 and h_6 functions as the connection m_1 in Fig. 12.

The above method may be used to repair disconnected red and blue data lines as well. Although Fig. 16 illustrated use of the secondary branch G_r of the central gate line G_i, it is possible to use secondary branch G_r of other gate lines to function as the connection between the disconnected data line and the repair line.

If the point of disconnection is known, the increase of RC delay resulting from repair may be reduced even more by using the following method. As shown in Fig. 17, assume the point of disconnection j is between the gate line G_{j-1} and G_j. The secondary branches G_r of gate lines G_{j-1}, G_1 are shorted (▲) at the crossing points with the disconnected green date line and the repair line 310 adjacent thereto, i.e., the points j_1, j_2, j_3 and j_4. The points outside j_5, j_6, j_7, j_8 of the shorted portions of the secondary branches G_r are disconnected with laser. Also the points outside j_9, j_{10} the shorted portions j_2, j_4 of the repair line 310 are disconnected with laser as well. As can be seen, the length of signal path after the repair is minimized and thus RC delay also is minimized.

On the other hand, by adding an additional connection to the third and fourth first preferred embodiments, a disconnected primary gate G_m may be repaired by sending gate signals through the additional connection and a secondary gate line G_r. Fig. 18 illustrates such a means of repair according to a fifth preferred first preferred embodiment of the present invention.

In Fig. 18, which shows duplicate gate lines of primary gate lines G_m and a secondary gate line G_r, the upper part and the lower part of a first connection 320 overlaps a data line 10 and connects to a secondary gate line G_r, respectively, and a second connection 330 connects to a primary gate line G_m and the upper part of the first connection 320. Each of the second connection 330 is formed for a predetermined number of pixels. The primary gate line G_m, the secondary gate line G_r, the first connection 320, and the second connection 330 are formed on the same layer.

The gate lines above are covered with a gate insulator (not shown) which is in turn covered with a semiconductor layer 20, which is comprised of an amorphous silicon layer and a highly-doped amorphous silicon layer. A source electrode 11, a drain electrode 12, and a data line 10 are formed on the same layer over the semiconductor layer 20. A data repair line 310 is formed for a predetermined number of pixels in parallel to the data line 10. A protective layer (not shown) is placed over the layer above. A contact hole 30 is formed on the protective layer on top of the drain electrode 12. A pixel electrode overlaps on top of the first connection 320 and the primary and secondary lines G_m and G_r and connects to the drain electrode 12 through the contact hole 30. Storage capacitance is generated at a point where the pixel electrode 40 overlaps the first connection 320 and the primary and secondary gate lines G_m and G_r.

The data repair line 310 is for repairing a disconnected data line as shown in Figs. 16 and 17. For example, suppose a data line 10 is disconnected at point k. The secondary gate lines G_r on above and below point k are shorted on the overlapping points k_1, k_2, k_3, and k_4 with the disconnected data line 10 and a data repair line in close proximity to point k. Then parts outside of the shorted secondary gate lines G_r defined between the shorted points are disconnected at points k_5, k_6, k_7, and k_8. As a result, data signals are sent below the disconnected point k_1 through the data repair line 320.

The first and second connections 320 and 330 are for repairing a disconnected primary gate line G_r. When a primary gate line G_r is disconnected, gate signals are sent by detour rout through the first connection 320, the second connection 330, and the secondary gate line G_m.

Although the data repair line 310 and the second connection 330 are formed for a plurality of pixels in Fig. 18, they may be formed each for a single pixel. Where they are formed each for a plurality of pixels, they should be each formed for a unit. Preferably, pixels should be grouped in units of three: red, green, and blue pixels. In particular, the data repair line 310 should be placed adjacent to a green data line as described in the third and fourth preferred embodiments of the present invention.

Although Fig. 18 does not have the second connection 330 overlapped with the pixel electrode 40, they may be arranged to be overlapped with each other and generate storage capacitance.

As described above, by repairing a disconnected data line according to the preferred embodiments of the present invention, the data repair lines may be shortened, which reduces electrical resistance and parasitic capacitance, thus minimizing picture signal distortion. Also, the present invention allows for repairing almost all data lines. Furthermore, the repairing process of a disconnected data line is substantially simplified by merely shortening two points on the data line without the disconnecting process if a data repair line has one side open according to an embodiment of the present invention.